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DEVELOPMENT OF A TISSUE FREEZING AND REWARMING DEVICE THAT USES COMPRESSED AIR AS A MEDIUM

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By
Mark W. Sharp SSG, Neil W. Ahle CPT,
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This report describes a tissue cooling/rewarming system (TCRS) which uses dried, supercooled, compressed air as a medium. It allows the user, in a manner close to that which occurs in a natural arctic environment, to freeze and rewarm animal tissue producing the first three degrees of frostbite. Temperature, wind speed and time of freeze can all be varied. The TCRS consist of an air compressor, air dryer, air jet cooler with controller, and a acrylic animal tissue freezing chamber. Temperatures are monitored by utilizing the Hewlett Packard 3054 A Data Acquisition System, which is driven by the Hewlett Packard 236 table top computer. The TCRS has been used to produce approximately 500 precisely controlled frostbite injuries to date. This TCRS should prove to be a useful means of developing a reproducible, realistic, animal frostbite model.

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ABSTRACT:

This report describes a tissue cooling/rewarming system (TCRS) which uses dried, super-cooled, compressed air as a medium. It allows the user, in a manner close to that which occurs in a natural arctic environment, to freeze and rewarm animal tissue producing the first three degrees of frostbite. Temperature, wind speed and time of freeze can all be varied. The TCRS consists of an air compressor, air dryer, air jet cooler with controller, and a acrylic animal tissue freezing chamber. Temperatures are monitored by utilizing the Hewlett Packard 3054A Data Acquisition system, which is driven by the the Hewlett Packard 236 table top computer. The TCRS has been used to produce approximately 500 precisely controlled frostbite injuries to date. This TCRS should prove to be a useful means of developing a reproducible, realistic, animal frostbite model.

INTRODUCTION:

Frostbite research has long suffered from the lack of a reproducible freezing method that mimics a natural arctic environment. Frostbite investigators have used many different methods to produce frostbite injuries. Examples of such methods include: direct contact liquid nitrogen cooling (1), direct contact immersion in a super-cooled bath (2), tissue protected by a barrier and then immersed into a liquid medium (3), and a method using a previously chilled branding iron (4). Limited control of the cooling variables and the exclusion of a wind chill factor prohibits any of the above methods from generating a realistic, reproducible animal frostbite model. To obtain such a model, a freezing technique, with precise cooling controls that is capable of mimicking an arctic environment is needed.

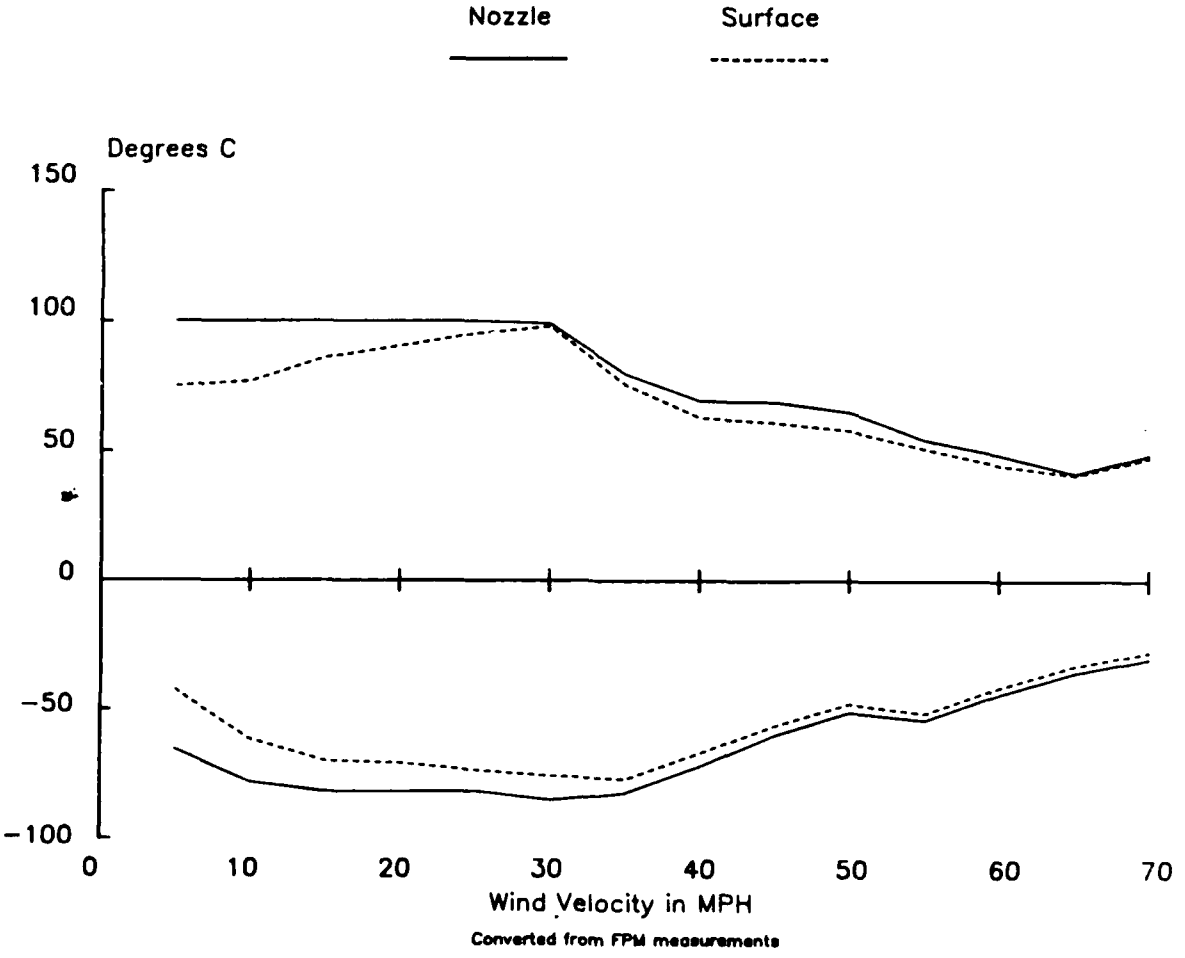
The objective of this report is to describe,(1) the means of producing super cooled or warm air as a medium for generating frostbite and rewarming the injured tissue, (2) the chamber that is deployed in freezing the tissue, (3) the methods of monitoring the temperature, flow rates, and duration of the freeze, and (4) the animal model and anesthetic that was utilized.

The Production of Super Cooled or Warm Air

The cooling or warming of air is accomplished by a system comprised of four components: a Quincy Model 5120 air compressor, a FTS model AD-80 Air Dryer, a FTS model XR-85-1 Air-Jet Crystal Cooler and a FTS model TC-44 Temperature Controller. The compressor requires 220 volts and has the capacity of providing 50 cubic feet per minute at 120 PSI. The air dryer operates on 115 volts and is capable of reducing 100 psi compressed air to a dew point of -80 degree centigrade. The air dryer contains a pressure regulator, pressure gauge, oil and particle filter and a heatless regenerative dryer. The dried air flow rate can be adjusted from .1 to 6 cfm. All flow rates were verified by utilizing a Alnor Velometer type 3002. After the air is dried it is then directed to the Air-Jet Cooler. The Air-Jet Cooler provides the cooling or warming of dry air. A thermocouple located in the nozzle is connected to a remote digital indicator/controller where the temperature is continuously displayed to 0.1 degree centigrade.A potentiometer is rotated to set any temperature over the range to the nearest 0.1 degree centigrade. The fast cycle rate controller provides power to the heater to bring the nozzle temperature to a previously determined set point. The controller

contains circuitry to prevent overshooting and automatic reset to provide control accuracy to ± 0.1 degree centigrade. The air flow can be adjusted from .1 to a maximum of 6 cfm although this alters the maximum and minimum achievable temperature range.(See fig.1.)

Maximum and Minimum Temperature Limits
for the TCRS



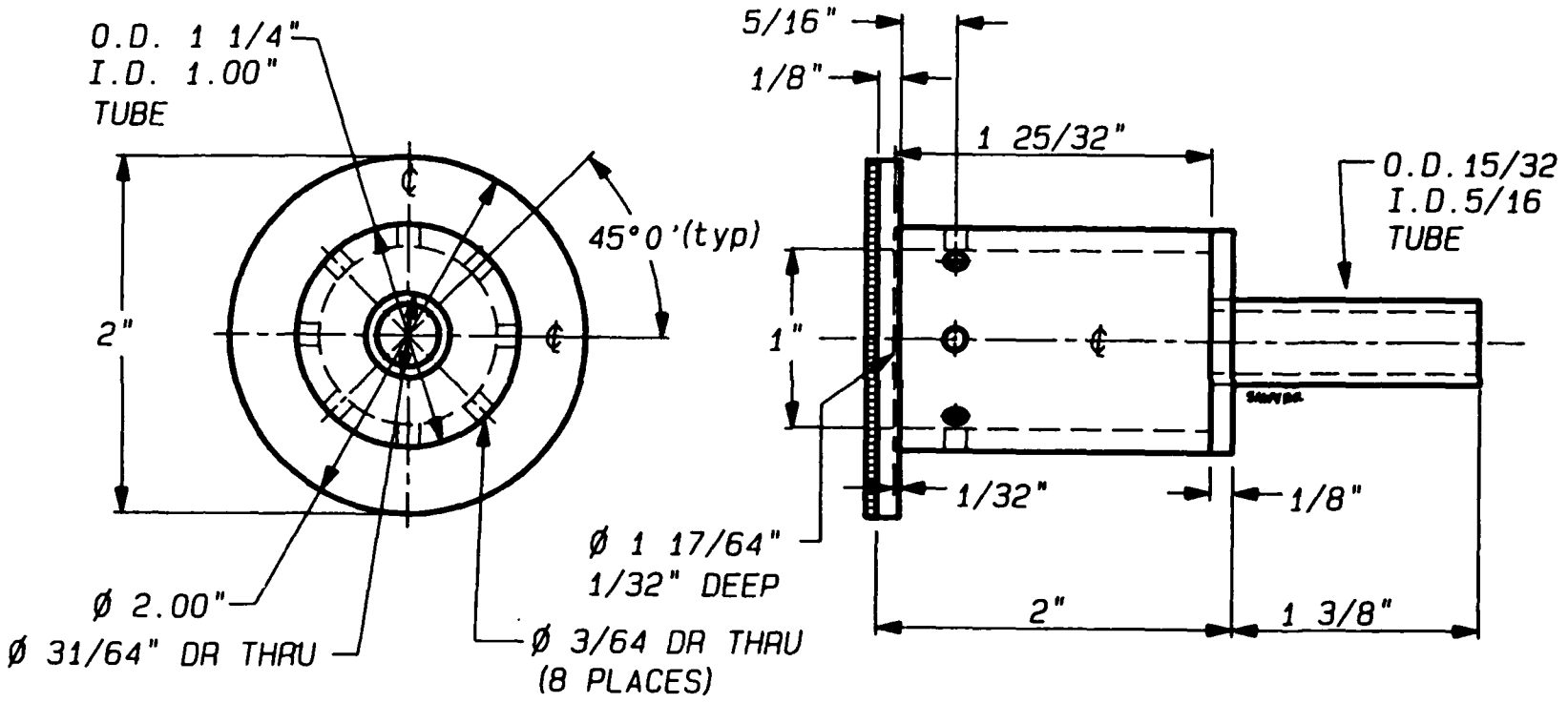
The Acrylic Animal Tissue Freezer

The Acrylic Animal Tissue Freezer,(AATF) was fabricated by the Biomedical Engineering Branch of the United States Army Institute of Environmental Medicine.(See fig.2.) The AATF is attached over the intended freeze area by utilizing double stick tape, model #A-20 tape #4016, manufactured by 3M, (St. Paul, Minnesota). A 7mil. paper air baffle was fabricated for the base of the AATF that would divert expelled air and reduce the possibility of accidentally freezing the surrounding tissue. This baffle was critical when freezing soft, easily depressed areas of the animal.(See fig.3&4)

The Data Acquisition System

The data acquisition system is comprised of four components: (1) a Hewlett Packard 3054A Data Acquisition system, (2) a Hewlett Packard 236 table top computer, (3) a Hewlett Packard Think Jet Printer, and (4) three different models of Omega T-type thermocouples. The three models deployed were the: (1) Omega Veterinary Implantation Probes used to measure rectal temperatures, (2) Omega HYP-0 used to measure intradermal temperatures, and (3) the Omega Insulated Teflon/Teflon .005 Dia. thermocouples utilized to

ACRYLIC ANIMAL TISSUE FREEZER

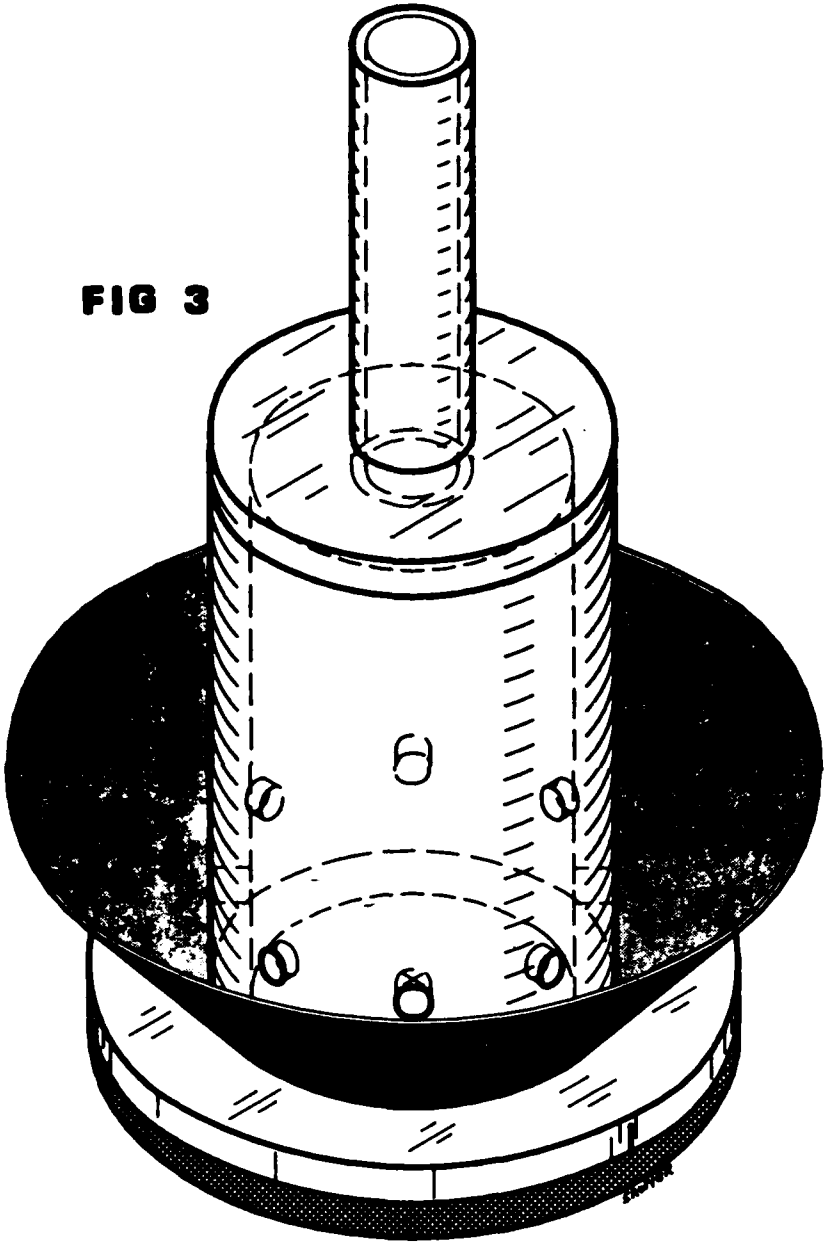


MATERIALS:

1. Acrylic body construction
2. Paper baffle, 7 mils thick see fig. 3 & 4
3. Acrylic adhiesive (trichloroethane)
4. Tape, urethane foam, double coated .065" thick

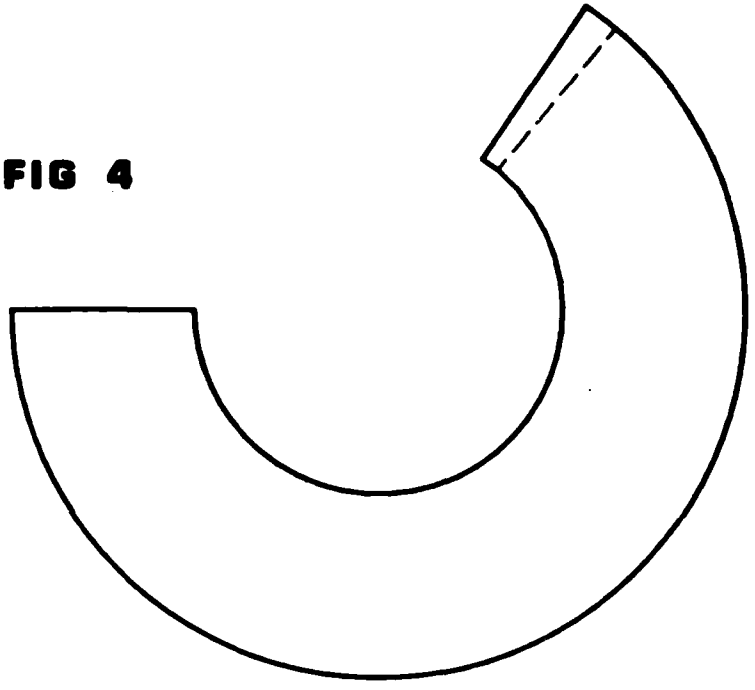
FIG 2

FIG 3



ORTHOGRAPHIC VIEW

FIG 4



BAFFLE PATTERN
(actual size)

measure skin, AAFT, air jet nozzle, and ambient temperatures. The computer is programmed to read the thermocouples every 4.5 seconds. A hard copy of the time and temperature information is generated by utilizing the HP Think Jet Printer. Simultaneously the same information is stored on one of the computer's internal 5-1/4 inch floppy disc drives for later analysis.

The Animal Model

The animal model that was selected was the Hanford (HMS tm) Miniature Swine which is bred by Charles River Breeding Laboratories, Inc. (Willmington, Massachusetts). Two successful methods of anesthesia employed during the freezing process were a Ketamine/Xylazine cocktail (20 mg/kg and 2 mg/kg respectively) given by intramuscular injection, or Halothane delivered by mask to effect. The animals were restrained by the Panepinto Sling Model #DL800, which is manufactured by the Dutton-Lainson Co. (Hasting, Nebraska).

Discussion

Frostbite researchers over the years have tried many different techniques in producing frostbite, most of which had either limited variability in the cooling process or did

not include factors such as wind chill. The AATF will give frostbite investigators a cooling method that has precise cooling controls, and is capable of mimicking a normal arctic environment. By possessing these two unique characteristics this cooling system should give future investigators the vehicle in which to produce a realistic, animal, frostbite model.

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